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Sustainability and Risk in Real Estate Investments: Combining Monte Carlo Simulation and DCF

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Abstract

This paper identifies the relative contribution of sustainability criteria to property value risk. We use a discounted cash flow (DCF) model to assess the effect of a given set of 42 sustainability sub-indicators on property value. The anticipated demand for each sustainability sub-indicator is described by four future states of nature. Their impact on costs and/or revenue is estimated and included in the model. Subjective probability distributions describe the occurrence of the future states of nature. Monte Carlo simulations of the DCF model are then used to estimate the impact of an individual feature on the risk (volatility) of the property value distribution. Our results for Switzerland show that 'use of thermal energy' (29.3%), followed by 'access to public transportation' (16.3%), 'day light' (9.6%) and 'story height' (6.3%) have the highest single impact on property value risk. The results are used for a risk-based weighting of a sustainability rating. The rating illustrates how sustainability criteria affect the risk of specific properties and is used as a basis for real estate investment decisions.‡

Keywords: Sustainability, Risk, Real Estate, Property, Value, Investments, Monte Carlo Simulation, DCF, Rating, Volatility

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I. Introduction

Real estate is of outstanding importance for sustainable development: buildings represent 32% of the final energy consumption worldwide (IEA - International Energy Agency, 2013). The rising awareness of this is reflected in the emergence of standards and certification schemes for sustainable buildings, like the environmental assessment system BREEAM or the green building program LEED, as well as in the increase in actually certified buildings. As of 2012 there are more than 24’600 certified LEED projects and more than 15’000 certified BREEAM projects worldwide (which corresponds to 250’000 certified BREEAM buildings). The strong dynamic in the market is illustrated by the fact that the number of projects registered for certification by far exceeds the number of actually certified projects (approx. by factor 2 and 2.5 respectively).[1]

But real estate is also of outstanding importance financially: the direct commercial real estate transactional market is estimated to amount to 450 billion US$ worldwide as of 2012 (Jones Lang LaSalle, 2013). The challenge is to assess, which investments are sustainable – both financially and non-financially.

From the point of view of a property owner or core investor, the success of a real estate investment is measured in terms of its financial performance (Bywater, 2011). A good investment has a relatively better financial performance or rather a lower risk of depreciation than the average market. The specific question with regard to sustainability from this perspective is therefore, which sustainability criteria result in a low risk of depreciation (Meins and Burkhard, 2007, Meins *et al.*, 2010) and lower volatility of return.

The majority of existing empirical evidence suggests that green buildings have higher sale prices and higher rental rates (for a recent overview of existing studies see World Green Building Council, 2013). Still there remains a general lack of awareness and knowledge regarding the link between sustainability and property risks (Lorenz and Lützkendorf, 2011). A deeper analysis is needed

[1] Source: www.usgbc.org and www.breeam.org

to account for the uncertainties in the variables that lead to the financial performance. The question, whether sustainable properties appreciate faster or depreciate slower than others, has not been answered so far (World Green Building Council, 2013).

In this paper, we take a step towards answering this question by identifying the relative contribution of selected sustainability criteria to property value risk. We use a discounted cash flow (DCF) model to assess the effect of a given set of 42 sustainability sub-indicators on property value. The anticipated demand for each sustainability feature is described by four future states of nature. Their impact on costs and revenue is estimated and included in the model. Subjective probability distributions describe the occurrence of the future states of nature. Monte Carlo simulations of the DCF model are then used to estimate the impact of an individual feature on the risk (volatility) of the property value distribution. The impact of each sub-indicator is determined by comparing the risk implied by the estimated property value distribution with and without each specific sustainability feature in question. Finally, we empirically determine the sustainability risk to be included in the discount rate.

We find that – as a result of the simulations for the residential sector in Switzerland – there are four sustainability sub-indicators that have the highest single impact on property value risk: 'use of thermal energy' (29.3%), followed by 'access to public transportation' (16.3%), 'day light' (9.6%) and 'story height' (6.3%). The results are used for a risk-based weighting of a sustainability rating. The rating illustrates how sustainability criteria affect the risk of specific properties and is used as a basis for real estate investment decisions.

Thus, the focus of this paper is – using the classification put forward by Lorenz and Lützkendorf, 2011– not on sustainable construction or sustainability assessment from a technical or engineering point of view, but rather on real estate investment. The results of the paper enable to link the questions of risk analysis and property valuation to performance measurement and reporting (Lorenz and Lützkendorf, 2011).

Organization of Paper

The remainder of this paper is organized as follows. Section II discusses the challenges and proposed solution to measuring sustainability in a real estate investment context. Section III deals with the operationalization of sustainability and section IV with the implementation of the weighting model. The results are presented in section V and illustrated by the application to an investor's portfolio. We critically appraise the results in the concluding section.

II. Measuring Sustainability for Real Estate Investments

The Challenge of Measuring Sustainability

While there are many guidelines and standards that focus on how to build sustainably or certify buildings that comply with certain sustainability criteria (these will be briefly discussed later on in this chapter), there is no global consensus on what establishes whether a building is sustainable or not and let alone a consensus on how to measure sustainability (Ellison and Brown, 2011). This poses a challenge for both practitioners, who are dependent on having certainty regarding the building standards, and academics, who depend on clear operational concepts for their studies.

The situation can be traced back to several reasons. First, the need to address sustainability arose at the same time in different real estate and construction markets around the world. Labels and standards developed in a bottom-up fashion as responses to particular interests. Thus the labels and standards were developed in parallel processes. Second, real estate and construction markets differ strongly depending on local conditions (regulatory, environmental, economic etc.). The emerging approaches are shaped by these specific conditions. Together with particular interests they pose impediments to attempts to coordinate and streamline the approaches. Finally, and most important to the line of argument of our paper, there is not one objective or exclusive answer to the question of what constitutes a sustainable property.

This lies in the nature of the concept of sustainability, which – according to the Brundtland definition – opts for a long-term balance between the environmental, social and economic dimension (World Commission on Environment and Development, 1988). Thus, sustainability is inherently a question of trade-offs and weighting between and within the different dimensions. In able to resolve the trade-offs, a normative judgment is necessary (although it helps to have objective scientific fundaments for the decision). Accordingly, the judgment may differ depending on the circumstances and individual perspectives.

While most approaches tend to be similar regarding the choice of sustainability criteria (focusing on energy consumption, health and comfort aspects etc.), certain differences between the criteria remain due to the selection process. The strongest differences, however, are revealed at the level of the measurement of the criteria and their weighting (e.g. how to measure “good air quality” and how to weigh it compared to “use of thermal energy”).

These differences are due partly to the necessity to take national or local conditions into account and partly due to the fact that the approaches have different end purposes. While some approaches aim at answering the question of “how to build sustainably ”, others aim at assessing “how sustainable a property” is. Among the first group are labels such as BREEAM, LEED or DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen – the sustainability system of the German Society for Sustainable Building) by the German Sustainable Building Council. They certify properties which comply with a defined sustainability standard and focus mainly on the construction process (new or refurbishment). Ratings such as BREEAM In-Use or the Swiss ESI-Rating – which this paper draws on – are among the second group. They are designed to assess how sustainable a property is and focus on newly constructed or refurbished buildings, but – and in contrast to before mentioned labels – on the existing building stock as well.

For a sound assessment of the degree of sustainability, a clear concept is needed. On one hand, the criteria on which the assessment is based need to be defined (sustainability criteria and their operationalization) and the underlying selection process needs to be transparent. On the other hand, it needs to be transparent how the trade-offs were resolved, i.e. how the different criteria or their indicators are weighted and how the weighing was derived.

Multidimensional versus unidimensional weighting

Since the general concept of sustainability focuses on a long-term balance of the environmental, social, and economic dimension, an obvious concept is to define assessment criteria for each dimension and then (equally) weigh the criteria of each dimension. Such a multidimensional weighting approach is tricky. First, the attribution of the criteria to the social environmental and economic dimension is challenging, as most criteria have an impact on more than just one dimension. The use of thermal energy, for instance, has an environmental but also an economic impact. How to clearly separate and quantify the multiple effects? Second, even if this succeeds and the criteria are weighted equally between the three dimensions, the weighting of the criteria within the dimensions remains unresolved. How is bio-diversity to be weighted compared to CO_2-emissions? Or how a comfortable environment for the user compared to a site that encourages social encounters among neighbors? Though economics in theory can contribute to answering how to integrate and weigh the three dimensions, for example by assessing the welfare implications of the depletion of natural capital and of positive or negative external effects, it is often not very meaningful to put them into practice, mainly because quantification poses great difficulties.

An alternative, more modest, concept is to select and weigh sustainability criteria according to one dimension, e.g. focus on the environmental effects and use an eco-balance as a basis for weighting. Or, as it is proposed in this paper for use in an investment context, to select and weigh sustainability criteria according to their economic impact.

An Individual, Financial Risk Based Perspective on Sustainability

Economic approaches to sustainability focus on the stability of the intergenerational consumption stream or the capital stock. The main aim is to keep consumption or capital at least intergenerationally stable (Perman *et al.*, 1996). To some extent, markets could solve the problem, but with market failures, under- or overuse of resources occur as well.

We measure the impact of sustainability criteria on capital stock (or economic value as labeled by Lorenz and Lützkendorf, 2011). In order to do this we, first, need to specify on which level the economic impact is assessed. A criteria's impact on a property can be assessed on the level of the economy as a whole (macro level) or on the level of a single individual (micro level). If it is to be assessed on a micro level, it must be defined on which individual level: e.g. the owner, occupier, or neighbor. According to our view on real estate investments, we focus on the micro level or, more specifically, on the level of the investor.

Second, we need to specify which time-frame the impact is measured on. This determines which measure of economic value to focus on. As is proposed for investors, we distinguish between market value or worth (Lorenz and Lützkendorf, 2011). If the short-term impact is to be assessed, the impact should be measured in terms of its impact on the market value of a property[2]. If, on the other hand, the long-term impact is to be assessed, it should be measured in terms of its effect on a property's worth or investment value. We chose investment value as a measure, due to our long-term investment perspective. In a nutshell, we assess the long-term risk of capital depletion for real estate for private investors.

As a consequence, we only take sustainability criteria into account that are relevant to private investors. This sounds more restrictive than it is in practice. The fact that some market failures (for example externalities) are not properly dealt with today, does not mean that they will not be taken into account in the future. If these possible evolutions are considered, it is not very likely that much of the relevant criteria have to be left out.

For an individual, financial risk based perspective, we define sustainability as follows: A sound investment in real estate requires an expected performance that takes its future risks properly into account. A **sustainable** investment in real estate reduces these risks as much as possible (therefore reducing the risk of capital depletion). Therefore, a sustainable investment has the lowest risk of depreciation within its asset subclass. Practically speaking, a property is sustainable from an investment point of view, when it is more future-proof, i.e. can deal with the consequences of long-term developments, such as climate change, rising energy prices or demographic change, and, therefore has a lower risk of depreciation (Meins and Burkhard, 2007, Meins *et al.*, 2010). This

[2] Methodologically, this could imply using a hedonic model to estimate the willingness to pay for certain sustainability features. To date, according to our knowledge, no rating exists with a weighting based on empirically determined willingness to pay for sustainability features.

definition is in line with the observation that, increasingly, sustainability is being viewed as a risk issue among property investors (Ellison and Brown, 2011) and determines the selection of the sustainability criteria used in this analysis.

III. Operationalization of Sustainability

The specification of the DCF is based on four pillars. The first consists of the sustainability criteria and their operationalization by the means of sub-indicators. Second, four possible states of nature are defined for the sub-indicators of each criterion. The possible states of nature range from the future development having no impact, to minimal, medium or maximal impact. Probabilities of occurrence are assigned for each state of nature. Third, the effects on costs and revenue in dependence of these sustainability criteria and the states of nature are depicted. These are used as the sustainability related input parameters for the DCF. Finally, the model draws on several other existing sources for all other (or “traditional”) real estate related input parameters.

Sustainability Criteria: Economic Sustainability Indicator

To operationalize the sustainability of properties from an investment point of view, we draw on an existing set of sustainability criteria, as defined and operationalized by the Economic Sustainability Indicator (ESI)[3]. The criteria are derived according to the definition of sustainability from an investment point of view as presented in the previous chapter. The selection and operationalization encompassed the following steps (as described in Meins *et al.*, 2010 and Meins *et al.*, 2012) and is used here for Swiss apartment buildings.

First, the long-term developments that are relevant for the worth of properties were identified. Those developments were selected for which scenarios with a clear trend exist or experts agree that a clear trend is highly probable. Second, property features were identified on which the selected long-term developments had an impact, i.e. property features which are likely to have an increased demand in the future. The resulting eleven features were assigned to five groups: flexibility, resource

[3] ESI is a joint development of the CCRS at the University of Zurich and representatives of the Swiss real estate sector and government. Originally developed to be integrated in DCF for valuations, the revised indicator now functions as a stand-alone rating.

consumption, mobility, safety, health and comfort (see Table 1). These represent the sustainability criteria from an investment view. Third, these criteria are operationalized, i.e. indicators were defined for each criteria (referred to as "sub-indicators") and coded. The coding occurs on a scale from +1 to -1, where +1 corresponds to favorable in terms of future demand (or "sustainable from an investment view"), -1 corresponds to unfavorable in terms of future demand (or "unsustainable from an investment view"). The result of the operationalization are 42 sub-indicators (see Table 2). For the detailed coding we refer to (Meins *et al.*, 2012).

Sustainability Criteria
1. Flexibility and polyvalence
1.1 Flexibility of use
1.2 Adaptability to users
2. Resource consumption and greenhouse gases
2.1 Energy and greenhouse gases
2.2 Water 2.3 Building materials
3. Location and mobility
3.1 Public Transport
3.2. Non motorized traffic 3.3 Location
4. Safety and security
4.1 Location regarding natural hazards
4.2 Building safety and security measures
5. Health and comfort
5.1 Health and comfort

Table 1: Sustainability criteria used in the Economic Sustainability Indicator (ESI)

Risk Estimates

Starting point for the risk estimates is the assumption, that long-term developments lead to a change in demand for the defined sustainability criteria and their sub-indicators. Four elements are needed to model these effects: scenarios (states of nature) depicting the likely bandwidth of future demand for the sustainability criteria as measured by the sub-indicators, probabilities for the states of nature, as well as impact on costs and/or revenue.

While the scenarios for the sub-indicators are formulated by researchers based on the identified long-term developments, the probabilities as well as the effects on costs and/or revenue are estimated by expert panels. These constitute the actual risk estimations or sustainability-related input parameters for the weighting model. The timeframe for the specifications is 30 years in the future. Obviously, this poses a challenge as estimating the effect of future changes of demand on cash flows is not an exact science. While the estimations can be based on the extent of existing effects, there remains a certain degree of subjectivity. In order to make the estimations as objective as possible, a two-step approach was taken: First, the experts carried the estimations out individually. In a second step, the estimations were verified by the expert panel as a whole. The panel consists of experts for construction costs (for the cost estimates) and valuation experts (for the revenue estimates).[4] In order to standardize the estimations as far as possible, the experts estimated the costs and revenue for a reference object. The details of the reference object as well as the scenarios, probabilities, costs, and revenue are discussed in the following.

The scenarios are used to describe the range of likely changes in future demand for the 42 sustainability sub-indicators. More specifically, the scenarios state the requirements, that properties may have to fulfill due to long-term developments in 30 years. For each of the sub-indicators, four states of nature are defined: They range from the Null, assuming there is no change in demand, to the maximum scenario, i.e. depicting the strongest likely degree of the effect, with a minimum and medium scenario depicting the likely graduations between the two extreme scenarios. Figure 1 illustrates the probability distribution (over these four states of nature) for ESI sub-indicator 1.1.1.

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[4] The estimations first took place in 2009 and were repeated in 2011. The 2011 panel consisted of the following experts: Iván Antón (Wüest+Partner), Hans-Peter Burkhard (CCRS-UZH), Sarah Frank (bauoek, Uni Stuttgart), Marcel Gilgen (EBP), Niels Holthausen (EBP), Markus Koschenz (Reuss Engineering), Susanne Leonhard (pom+), Philippe Lobstein (Karl Steiner), Erika Meins (CCRS-UZH), Frank Meinzer (RICS Switzerland / Schofield & Partners), Bernd Sturm (Karl Steiner), and Rolf Truninger (Qualicasa).

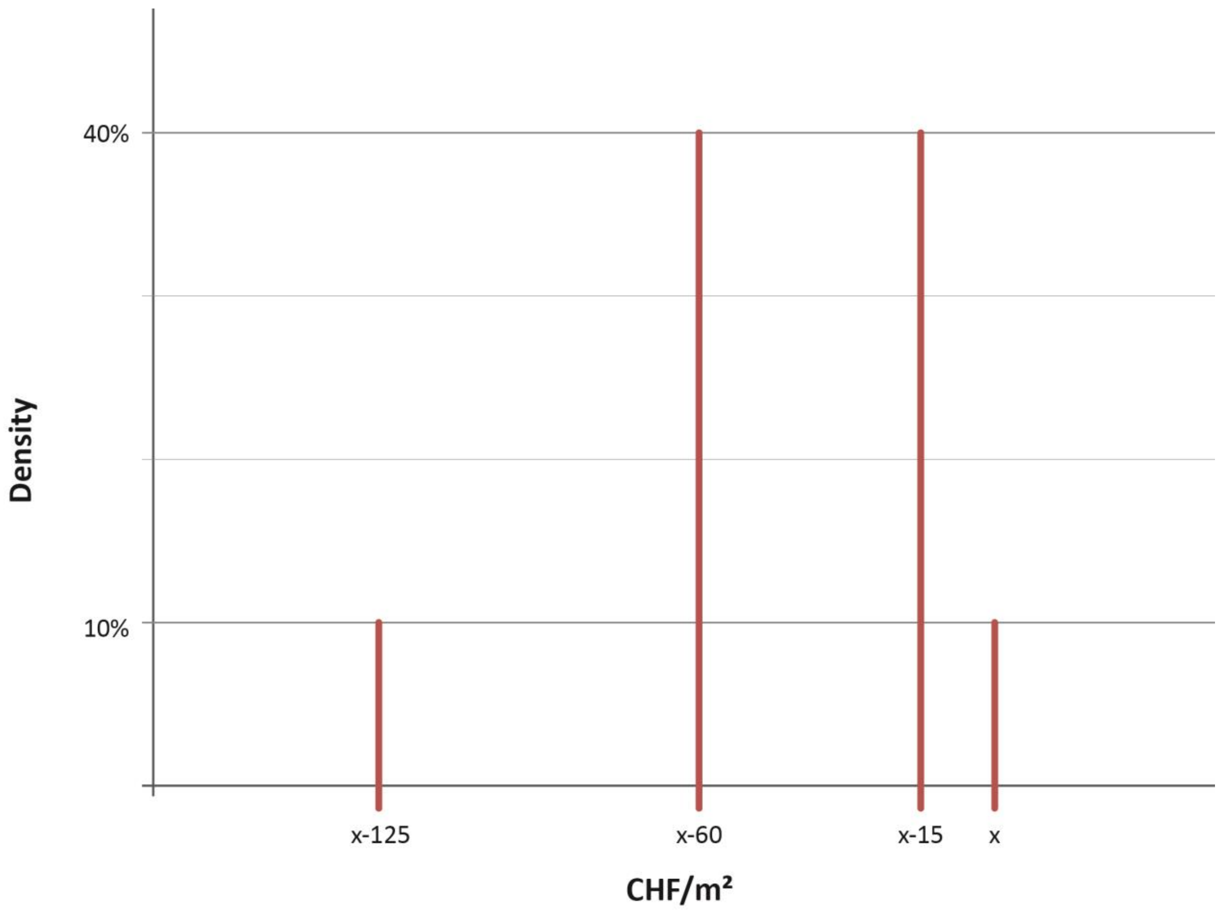

Figure 1 Distribution of effect of ESI sub-indicator 1.1.1 – floor plan on cash flow (x) depending on state of nature

The estimated probabilities stand for the likeliness that properties will need to meet the future demand as specified by the four scenarios. The probabilities have values between 0 and 1 for each state of nature, the sum of all probabilities equals 1.

The estimated costs depict the consequence of each sub-indicator and state of nature, assuming the state occurs. The consequence is estimated under the assumption that the property does not meet the future demand or, more specifically, that the property has a specification of the sustainability feature that corresponds to -1 ("unsustainable" – also referred to as "ESI type -1" for the model specification). The costs are measured in Swiss Francs per square meter gross floor area for the reference object. Furthermore, the costs are estimated as additional costs, that incur within a regular restoration. To make allowance for the fact that there is uncertainty associated with the estimations, bandwidths were estimated for the cost estimations. This results in a triangular distribution of the estimates. If a restoration to meet the future demand is not possible (e.g. the demand is linked to the location) or not likely to pay off in terms of cost/benefits (e.g. increasing the height between floors), then the effect is not estimated in terms of costs but in terms of reduced revenue.

The estimated revenues depict the consequence of each state of nature assuming the state of nature occurs. Like for the cost estimates, the consequence is estimated under the assumption that the property has a specification of the sustainability feature that corresponds to -1 (“unsustainable”).The revenues are estimated in terms of a percentage reduction of the rental revenues with regard to the reference object. Like for the cost estimates, bandwidths were estimated for the revenue estimations to account for the uncertainty associated with the estimations.

As a reference object an apartment building was used, which corresponds to an average Swiss apartment building in the lower price segment. The standard of the building is simple and it was constructed in 1950. For further details on the reference object, we refer to Meins *et al.*, 2012.

IV. Model Specification

Financial theory provides models for the quantification and for the pricing of risk in market equilibrium (e.g. Capital Asset Pricing Theory). For real estate in general the question, whether these models fully apply or not, remains unsolved, and even the more, in the case of direct real estate (see e.g. Geltner and Miller, 2001, Ooi *et al.*, 2009). In this case, questions arise whether risk premia include compensations for unsystematic risk, liquidity, compensation for above average exposure to legal changes and information costs (Damodaran, 2012).

If risk premia could be properly measured, and expected cash flows properly forecasted, DCF valuations should exactly estimate real estate market value. Increasingly, there is awareness, that there are uncertainties underlying the valuation process, that lead to a violation of this oversimplistic view (see for example Bywater, 2011). Where uncertainties about risk premia or expected cash flows arise, general methods of risk analysis can be used to quantify this uncertainty. In practice, this amounts to sensitivity or scenario analysis or to the probabilistic formulation of uncertainties and Monte Carlo simulations[5].

Monte Carlo simulations have been described as a possibility for risk analysis in the context of investment appraisal for quite some time (for example Savvides, 1994). They are especially suitable in cases where non diversifiable risks strongly affect the value of an investment (for example in the case of nuclear power plants Rode *et al.*, 2001). In the case of DCF valuations for real estate, they have been applied by Hoesli *et al.*, 2005.

The issue whether risk premia can be properly measured or not aside, they can only be related to developments that can be measured with historical data. Therefore, they would only be accurate, if underlying historic states of nature also apply to the future, i.e. no structural interruptions or new trends have occurred. We argue that issues like limited natural resources may therefore not be covered sufficiently by historical data. The ESI-Indicator is specified to capture these developments that assumedly affect risk in future and cannot be measured with historical data, either because of non-existence of such data or because of completely new states of nature.

Quantifying Risk that Cannot be Measured Historically

In investment appraisal (not necessarily real estate), the steps for risk analysis with Monte Carlo simulations are well described (Savvides, 1994):

1. determine an appraisal model
2. determine (objective or subjective) probability distributions of future outcomes
3. separate important from unimportant variables in appraisal model, based on the sensitivity of the result with regard to the variable
4. identify and describe correlations of future outcomes

In our case, the appraisal model is a discounted cash flow model, as proposed by Muldavin, 2010 and Lorenz and Lützkendorf, 2011. As it is used to determine the contribution of ESI sub-

[5] Not all uncertainties can be expressed with probability distributions however. See Bywater (2011) for a possible terminology of uncertainties.

indicators to risk, we use a slightly reduced DCF structure, for example excluding expected average vacancy:

$$P_t = \sum_{t=0}^{100} \frac{R_t - (O-M)_t - M_t - Capex_t}{(1+\rho)^t} \qquad (1)$$

where

R	gross rental income
(O-M)	operating – maintenance cost
M	maintenance cost
Capex	capital expenditure
ρ	discount rate (equity financed, not WACC)
t	time index

For this model we fully describe "all" possible future outcomes for an average residential building. Initial values are taken from the average (apartment) building of the Database of the (Swiss) Real Estate Investment Data Association (REIDA), which reflects the holdings of institutional investors. Future outcomes are divided in two parts:

a) future outcomes that can be modeled by historical processes, such as rental income and construction cost evolution. These series are thought to exhibit serial correlation.

b) future outcomes that cannot be modeled by historical processes: these are captured by the ESI sub-indicators, which are chosen in a way as not to be correlated. Furthermore, each ESI sub-indicator is furthermore assumed to occur between period 10 und 40 of the DCF model, based on a uniform probability distribution.

Figure 2 represents the effect of two ESI sub-indicators on the cash flows in one simulation:

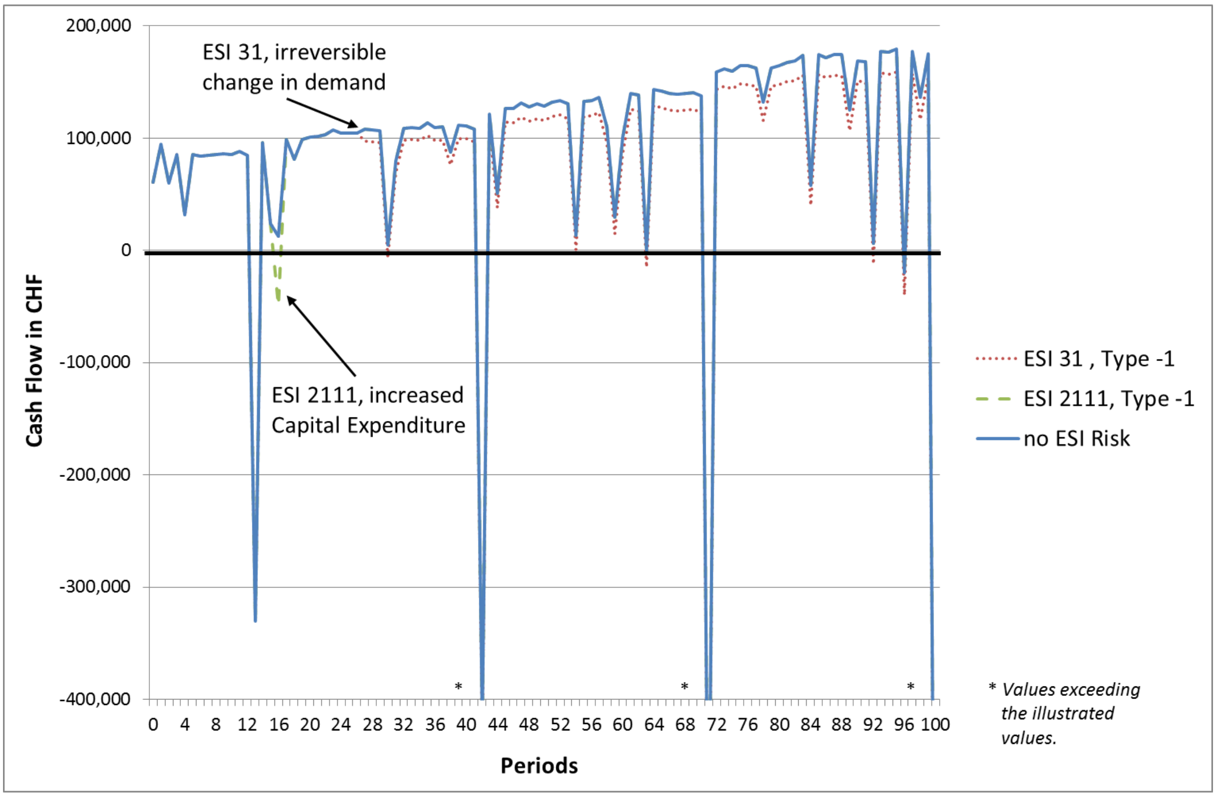

Figure 2: Effect on Cash Flows in one simulation run of indicator "poor access to public transport" (ESI 3.1) and of ""high use of thermal energy" (ESI 2.1.1.1) for ESI Type -1

The revenue and operating as well as renovation cost series follow historical cyclical patterns, whereas ESI risks take place from year 10 – 40 with a specific realization according to their subjective probability distribution. Figure 2 illustrates how around period 15 "high use of thermal energy" negatively affects demand. However, the effect is reversible by renovation and therefore there is only a one period reduction in cash flow. In period 27 the risk "poor access to public transport" negatively affects demand. This risk is irreversible and revenue reduction continues throughout the simulation period.

The different cash flow paths are discounted to their present value using the riskless rate. When applying Monte Carlo methods to valuation, most authors use discount rates including risk premia. In our opinion this is justified, if Monte Carlo simulation is used to analyze a certain aspect of uncertainty, which is not covered by the valuation model itself. An example are non-diversifiable risks in a model, where the discount rate risk premium covers only diversifiable risk.

In our case however, we fully model all likely future paths of the cash flows, each of which is a realization of the underlying probability distributions. This is different from calculating a DCF model based on expected cash flows. The realization which will occur will be certain and therefore it seems to be correct to discount this income stream with a riskless rate. The quantity of risk corresponds then to the volatility of all possible valuations derived from all possible realizations of future outcomes and their respective frequency. This approach is in line with Hughes, 1995 and quite similar in spirit to the present value distribution model (PVD).

Figure 3 shows the simulated distribution of property values for ESI sub-indicator 2.1.1.1. for ESI-Type -1 when ccoompared to a simulation containing only historical evolutions ("no ESI risk"). The damage in the different states of nature shifts the distribution to the left, the most for the state of nature with maximum damage. The "Null" state of nature spans the same range of values as the simulation without ESI risks (because the risk takes no effect in this case). Because this state covers only 10% of the future states of nature, the curve is much flatter.

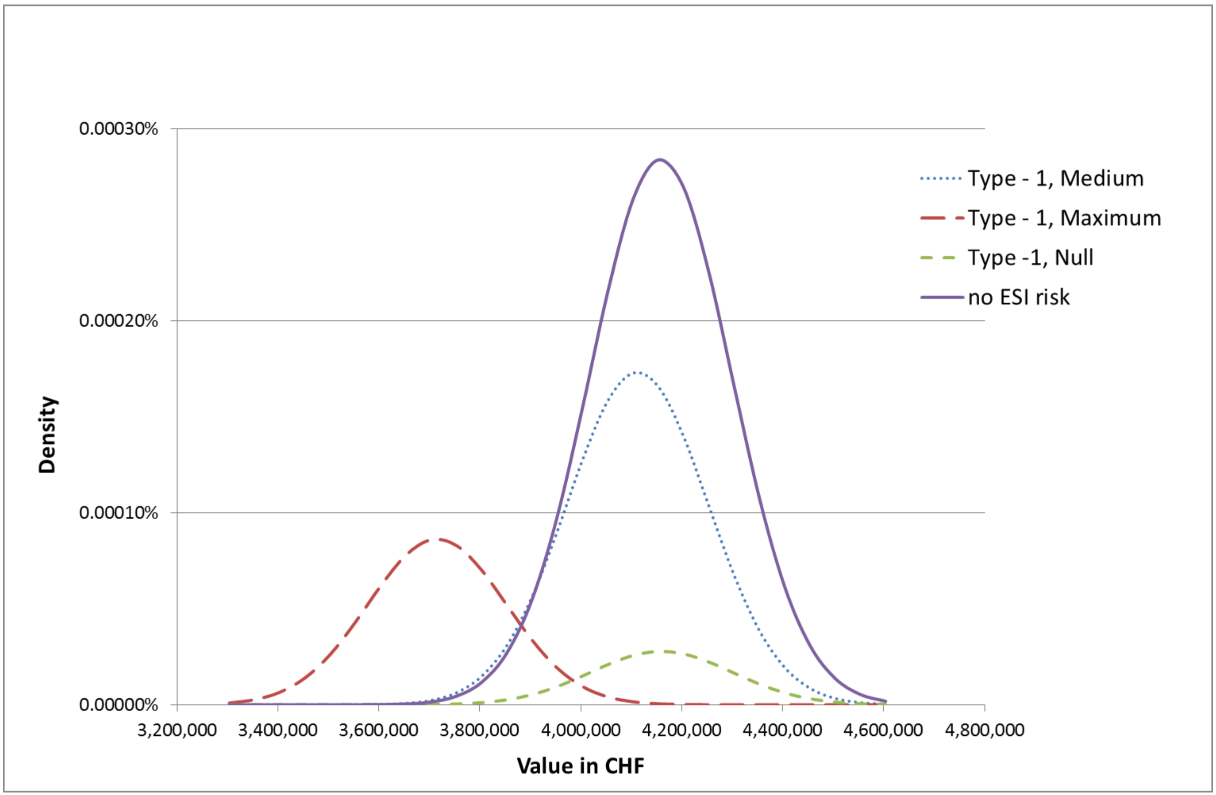

Figure 3: Distribution of estimated property values with ESI sub-indicator 2.1.1.1. and without ESI sub-indicator for ESI-Type -1

Deriving the correct discount rate

The average present value estimated by the simulation runs does not correspond to an actual valuation, since this value does not take into account that the investment is risky. Therefore a price of risk has to be applied to the quantity of risk derived by the Monte Carlo simulations. For this purpose, we use the Sharpe Ratio of Swiss Funds.

The thereby derived discount rate can then be applied to the average estimated cash flows from the simulation in order to calculate the estimated discounted cash flow value.

Deriving the weights for the sustainability criteria

Weights for the sustainability criteria as measured by ESI are derived by the following calculation:

$$W_{ESI\ x} = \frac{DR_{ESI\ x} - DR_{no\ ESI}}{\sum_{y=1}^{N} DR_{ESI\ y} - DR_{no\ ESI}} \quad (2)$$

where

$W_{ESI\ x}$ weight of ESI sub-indicator x

$DR_{ESI\ x}$ discount rate calculated based on simulation with ESI sub-indicator x

$DR_{no\ ESI}$ discount rate calculated based on simulation without ESI sub-indicators

N number of ESI sub-indicators

Therefore the weight depends on the relative contribution of an individual ESI sub-indicator to the discount rate.

Alternatively to this solution, the discount rate could be calculated with all ESI sub-indicators and compared to the discount rate with the specific ESI sub-indicator missing. As there are 42 ESI sub-indicators, the number of different realization paths is extremely large. This in turn increases the number of simulation runs required in order to reach stable results. Therefore function (2) is applied for practical reasons.

V. Results

A. Relative contribution of selected sustainability criteria to property value risk

The results show that in Switzerland, apartment buildings with a low consumption of thermal energy, good access to public transportation, sufficient day light, and generous story height have the relative lowest risk of depreciation, since these four sustainability sub-indicators have the largest single impact (29.3%, 16.3%, 9.6% und 6.3%, see Table 2). Thereby they account for almost two thirds of the total measured risk.

On the other hand, the use of renewable energy has a lower impact (thermal energy 0.17% and electricity 0.22%). The use of renewable energy does also contribute to a lower risk of depreciation, however, the effect is negligible. This may be traced back to the fact that the use of renewable energy usually can be adapted later on, e.g. by an installation of heat pumps or solar panels. Features that are specific to the location, however, like access to public transportation or structural features like the story height are not or not easily changed. These features obviously pose a higher risk.

At the level of the five groups of aggregated sustainability criteria, 'resource consumption and greenhouse gases' has the highest relative weight (32.1%), followed by 'health and comfort' (30.6%), 'location and mobility' (22.5%), 'flexibility' (13.5%), as well as 'safety and security' (1.3%). The results as indicated are quite stable: With 20’000 simulation runs led to a variation within 10% for a weight of 1% (a weight of 1% could therefore be 1.1% of 0.9% as well).

Sustain. Criteria	Sub-Indicators	Weighting		
1. Flexibility and Polyvalence	**1.1 Flexibility of use**		**6.6%**	**13.5%**
	1.1.1 Floor plan	0.35%		
	1.1.2 Storey height	6.26%		
	1.1.3 Accessibility wiring / pipes / building services	0.02%		
	1.1.4 Reserve capacity wiring / pipes / building services	0.02%		
	1.2 Adaptability to users		**6.9%**	
	1.2.1 Lift (wheelchair accessible) existing for all stories if multistory	0.87%		
	1.2.2 Manageable differences in height, interior and exterior	0.01%		
	1.2.3 Sufficiently wide doors	1.11%		
	1.2.4 Sufficiently wide halls	1.09%		
	1.2.5 Wheelchair accessible washrooms	0.00%		
	1.2.6 Flexibility of kitchen layout	0.04%		
	1.2.7 Storage of walker / pram	0.87%		
	1.2.8 Usability of outside space	2.89%		
2. Resource Consumption and Greenhouse Gases	**2.1 Energy and greenhouse gases**		**31.6%**	**32.1%**
	2.1.1 Energy demand			
	2.1.1.1 Thermal heat usage (MJ/m^{2}a)	29.26%		
	2.1.1.2 Cooling	1.97%		
	2.1.2 Use of renewable energy			
	2.1.2.1 To cover warming needs	0.17%		
	2.1.2.2 To cover electrical needs	0.22%		
	2.2 Water		**0.2%**	
	2.2.1 Water use	0.01%		
	2.2.2 Wastewater disposal	0.08%		
	2.2.3 Rainwater use	0.08%		
	2.3 Building materials		**0.3%**	
	2.3.1 Recyclable building materials	0.28%		
3. Location and Mobility	**3.1 Public Transport**		**16.3%**	**22.5%**
	3.1.1 Connection to public transport	16.32%		
	3.2. Non motorized traffic		**1.1%**	
	3.2.1 Bicyle parking	1.11%		
	3.3 Location		**5.0%**	
	3.3.1 Distance to local / regional center	1.27%		
	3.3.2 Distance to shopping facilities of daily needs	1.21%		
	3.3.3 Distance to recreation area / parks	1.18%		
	3.3.4 Prestige-location / excellent (triple A) location	1.38%		
4. Safety and Security	**4.1 Location regarding natural hazards**		**1.0%**	**1.3%**
	4.1.1 Location regarding risk of natural hazards (increasing flood, avalanche, landslide)	1.01%		
	4.2 Building safety and security measures		**0.3%**	

	4.2.1 Object related safety and security measures			
	4.2.1.1 Object relates safety and security measures concerning flood	0.10%		
	4.2.1.2 Object relates safety and security measures concerning earthquake	0.09%		
	4.2.2 Person related security measures			
	4.2.2.1 Lightning / illumination	0.05%		
	4.2.2.2 Fire protection	0.10%		
5. Health and Comfort	**5.1 Health and Comfort**			**30.6%**
	5.1.1 Inside air quality	1.21%	**1.2%**	
	5.1.2 Noise exposure		**3.4%**	
	5.1.2.1 Exterior noise exposure	2.33%		
	5.1.2.2 Interior noise exposure airborne sound	0.43%		
	5.1.2.3 Interior noise exposure impact sound	0.33%		
	5.1.2.4 Noise from building service equipment and fixed facilities in building	0.35%		
	5.1.3 Sufficient natural light	9.62%	**9.6%**	
	5.1.4 Radiation exposure		**9.6%**	
	5.1.4.1 Electromagnetic pollution (non-ionizing): mobile antenna	1.64%		
	5.1.4.2 Electromagnetic pollution (non-ionizing): electric power network	4.92%		
	5.1.4.3 Radon (ionizing)	3.03%		
	5.1.5 Construction materials		**3.3%**	
	5.1.5.1 Ecological construction materials in new buildings	1.66%		
	5.1.5.2 Material with adverse health effects in old buildings	1.66%		
	5.1.6 Inherited pollution	3.41%	**3.4%**	

Table 2: Sub-Indicators of the Economic Sustainability Indicator ESI and their weights

B. Application: risk-based weighting system for property sustainability rating

These findings can be used in practice to weigh sustainability criteria for investment decisions as an additional information next to revenue indicators. The Economic Sustainability Indicator (ESI) assesses the sustainability criteria of a property regarding their relative risk of depreciation. The indicator takes values from -1 to +1: whereby positive values indicate that there is potential for appreciation, negative values indicate a relative risk of depreciation.[6] The rating is illustrated for a portfolio of a Swiss institutional investor (Figure 4). The IFCA-portfolio of Swisscanto consists of 129 apartment buildings with an estimated value of CHF 1'227 million.

[6] The rating can be used online (German and French): www.esiweb.ch

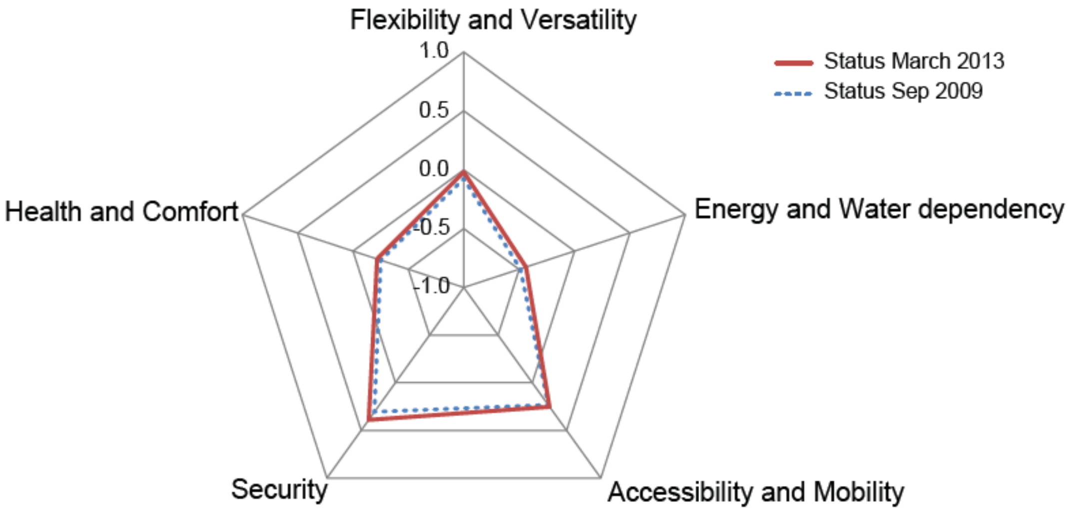

Figure 4: ESI-Rating of a portfolio of a Swiss institutional investor (CHF 1'227 million)

Approximately two thirds of the properties in the portfolio were built between 1960 and 1970. This is reflected in the radar diagram in Figure 4. It shows that the portfolio performs above-average in regard to accessibility and mobility as well as security. Potential for improvement remains by energy- and water dependency as well as health and comfort. This potential shall be tapped in the next refurbishment cycle during the next five to ten years. Thereby an average value of the ESI-Indicator of at least 0.0 will be targeted by the investor. The slight improvement of the values from 2009 to 2013 show that the portfolio is already on the right track. The investor also systematically uses the information generated by the rating to estimate the potential of individual properties: what can be improved with reasonable effort and what not?

The ESI-Rating can also be used to document the degree of sustainability of a property for valuation reports. In Switzerland this has been mandatory since 2012, when the Swiss Valuation Standards (SVS) were revised and now require an explicit documentation and assessment of sustainability for each property valuation (RICS Switzerland, 2012).[7]

[7] The SVS refer to the tri-national NUWEL guidelines (Nachhaltigkeit und Wertermittlung Leitfaden, 2011) and checklist for the implementation of sustainability. ESI is compatible with the NUWEL checklist and can be used to assess as well as document the sustainability of a property in valuation reports.

VI. Conclusions

By quantifying the link between sustainability and the risk of depreciation this paper founds sustainability ratings in financial theory. Thereby it provides a basis for integrating sustainability to risk management and portfolio theory as is postulated by Krysiak, 2009.

Methodologically it poses a further development by linking Monte Carlo simulations to a DCF to assess the impact of changing market conditions related to sustainability on the estimated worth, as suggested by Lorenz and Lützkendorf, 2011. At the level of measurement, this knowledge can be used for a financial sustainability rating, which allows investors to make informed decisions between risk and expected benefits when managing real estate investments. The results can also be used as a risk documentation for valuation or for reporting purposes, as postulated by Lorenz and Lützkendorf, 2011.

As our results apply to apartment houses in Switzerland, future research will need to focus on other markets – geographically and types of real estate. Some questions with regard to the details of our approach need attention in future research as well: These are the case for riskless discounting, application of the term structure of interest rates as well as transformation of value distributions to risk measures (actually done by means of a Sharpe Ratio).

Further limitations of the approach lie in the input data. This is especially crucial when dealing with estimations of the future as is the case here. We tried to account for this by a careful selection of experts and an estimation process that facilitated independent estimations. Apart from that, the results are intended to be used as an additional, objective foundation for investment or valuation decisions and they – as is the case with all tools – do not replace common sense.

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